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The added economic and environmental value of plug-in electric vehicles connected to commercial building microgrids

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Outline



- global concept of microgrid and electric vehicle (EV) modeling
- Lawrence Berkeley National Laboratory's Distributed Energy Resources Customer Adoption Model (DER-CAM)
- example EV connection to an office building, optimal interaction with a microgrid
- example demand response, CO₂ tax, annual building energy costs, CO₂ emissions

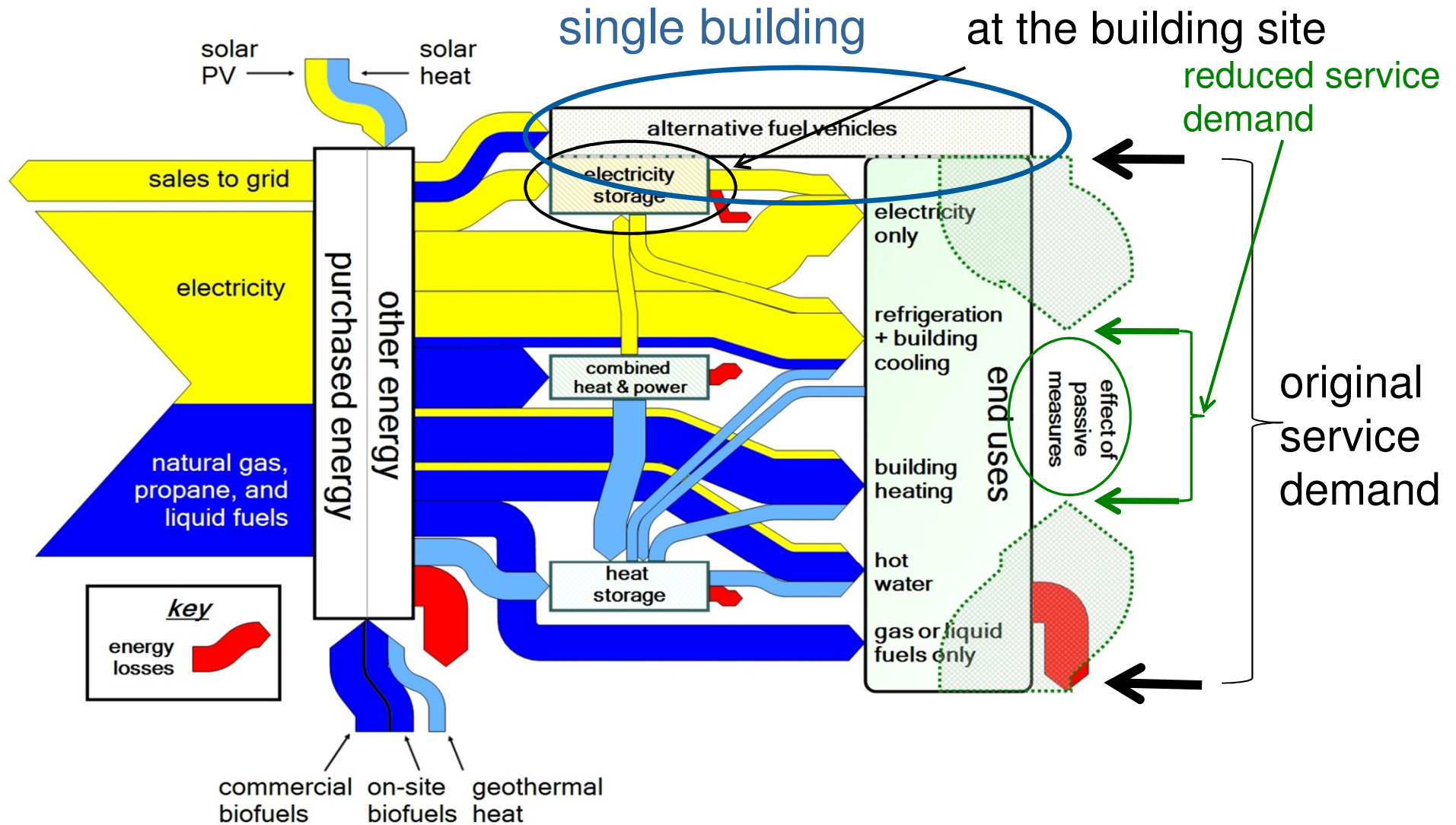
Do EVs support financial as well as environmental benefits of on-site generation at microgrids?

- conclusions



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Global concept





The Distributed Energy Resources Customer Adoption Model (DER-CAM)



DER-CAM



- is a deterministic Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- minimizes annual energy costs, CO₂ emissions, or multiple objectives of providing services to a building microgrid
- produces technology neutral pure optimal results, delivers investment decision and operational schedule
- has been designed for more than 9 years by Berkeley Lab and collaborations in the US, Germany, Spain, Belgium, Japan, and Australia → exchange visitors
- first commercialization and real-time optimization steps, e.g. Storage & PV Viability Optimization Web-Service (SVOW), <http://der.lbl.gov/microgrids-lbnl/current-project-storage-viability-website>





2020 Equipment Options, Tariffs, and Building Analyzed



Equipment



- EVs belong to employees/commuters
- EVs can transfer energy to the office building and vice versa
- the building energy management system (EMS) can manage (charge/discharge) the EV batteries during office hours
- EV owner receives exact compensation for battery degradation and receives a fixed amount of \$80/year

EV-building connection period	9am – 6pm
EV-home connection period	8pm – 7am
EV battery state-of-charge (SOC) when arriving at the office building	73%
EV battery SOC when leaving the office building	$\geq 32\%$
EV battery charging efficiency	95.4%
EV battery discharging efficiency	95.4%
EV battery capacity	16 kWh
Maximum EV battery charging rate	0.45 [1/h]

Equipment



- also combined heat and power (CHP), PV, solar thermal, stationary battery, etc. is considered
- technology costs in 2020 are based on “Assumptions to the Annual U.S. Energy Outlook”, e.g.
 - fuel cell (FC) with heat exchanger (HX): \$2220 - \$2770/kW, lifetime: 10 years
 - internal combustion engine (ICE) with HX: \$2180 - \$3580/kW, lifetime: 20 years
 - PV: \$3237/kW, lifetime: 20 years
 - stationary battery: \$193/kWh
 - etc.

Details can be found in full paper.



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Building / tariffs



- electricity and gas loads for a San Francisco Bay Area office building are passed on the California Commercial End-Use Survey (CEUS)
 - peak electric demand: 373 kW
 - annual electricity demand: 1.677 GWh
 - annual natural gas consumption: 0.713 GWh
- TOU rates and demand charges:
 - on-peak electricity up to 0.16 \$/kWh
 - off-peak rates around 0.10 \$/kWh
 - Demand charges up to 10.27 \$/kW-month
- electric rate at residences (homes): \$0.062/kWh (plus any CO₂ price)

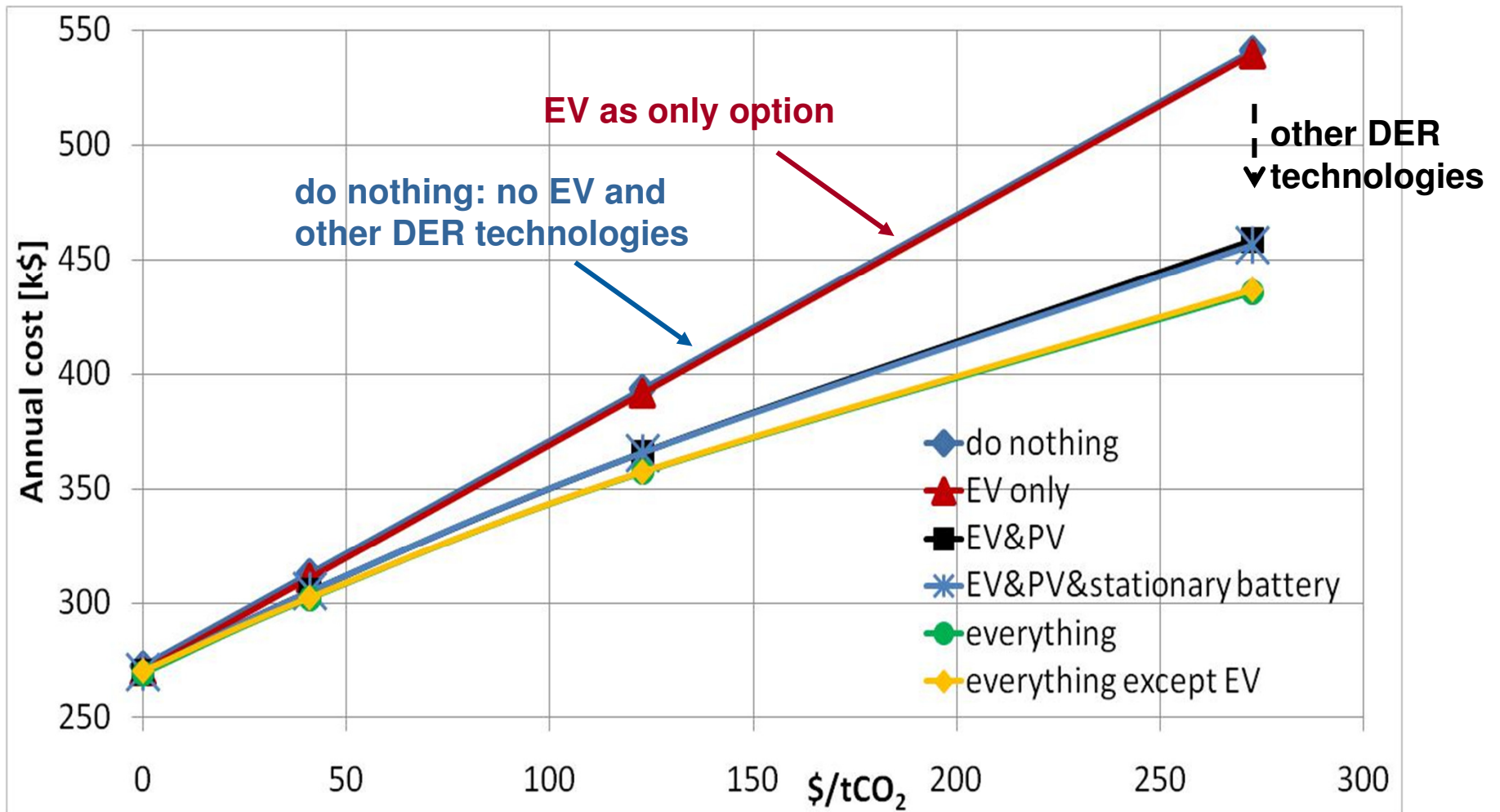




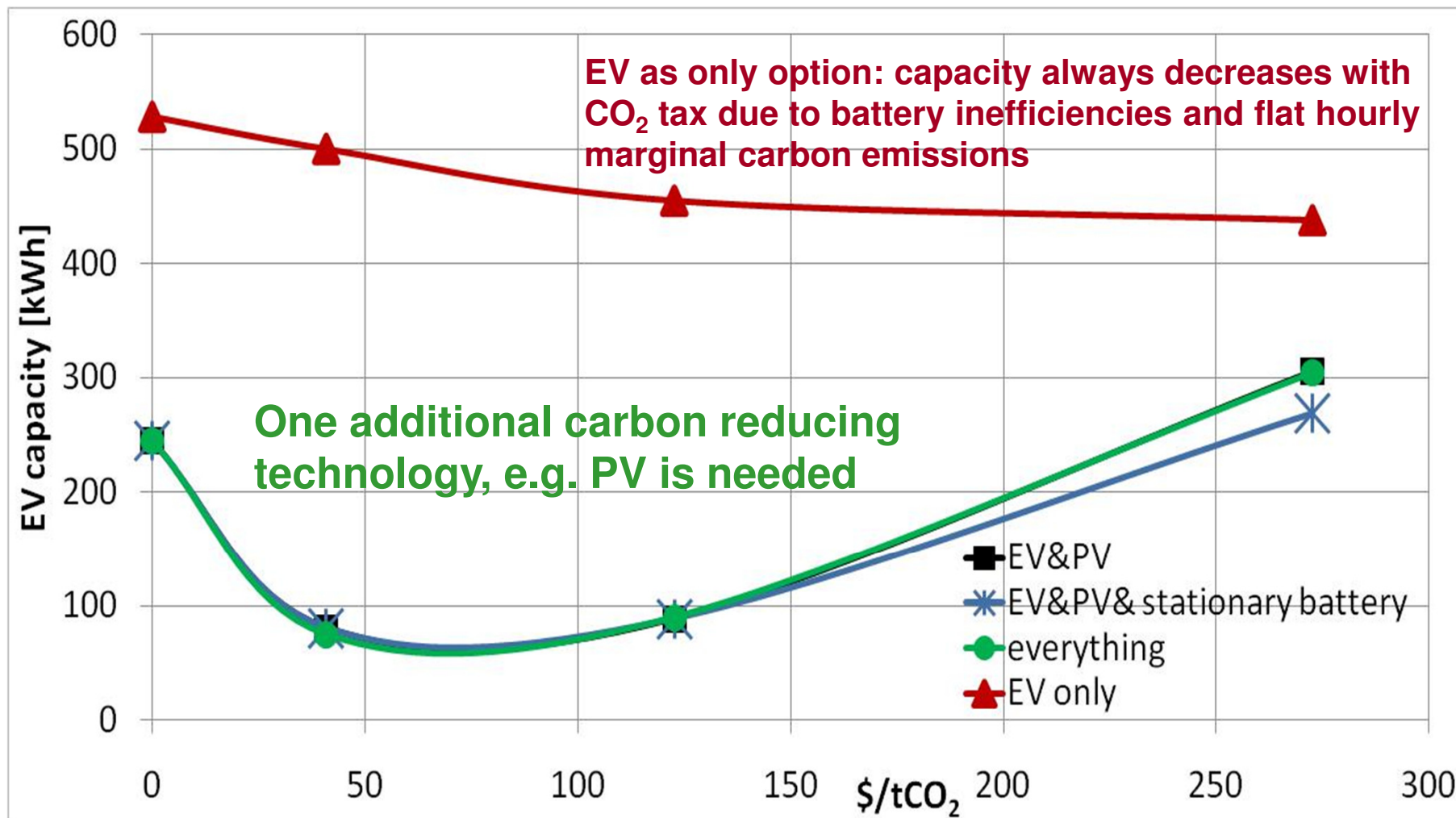
Optimization Results

**Optimal Investments in DER
Technologies and Operation,
Optimal EV Discharging / Charging
to Minimize Energy Costs at Office
Building**

Building energy costs vs. CO₂ tax



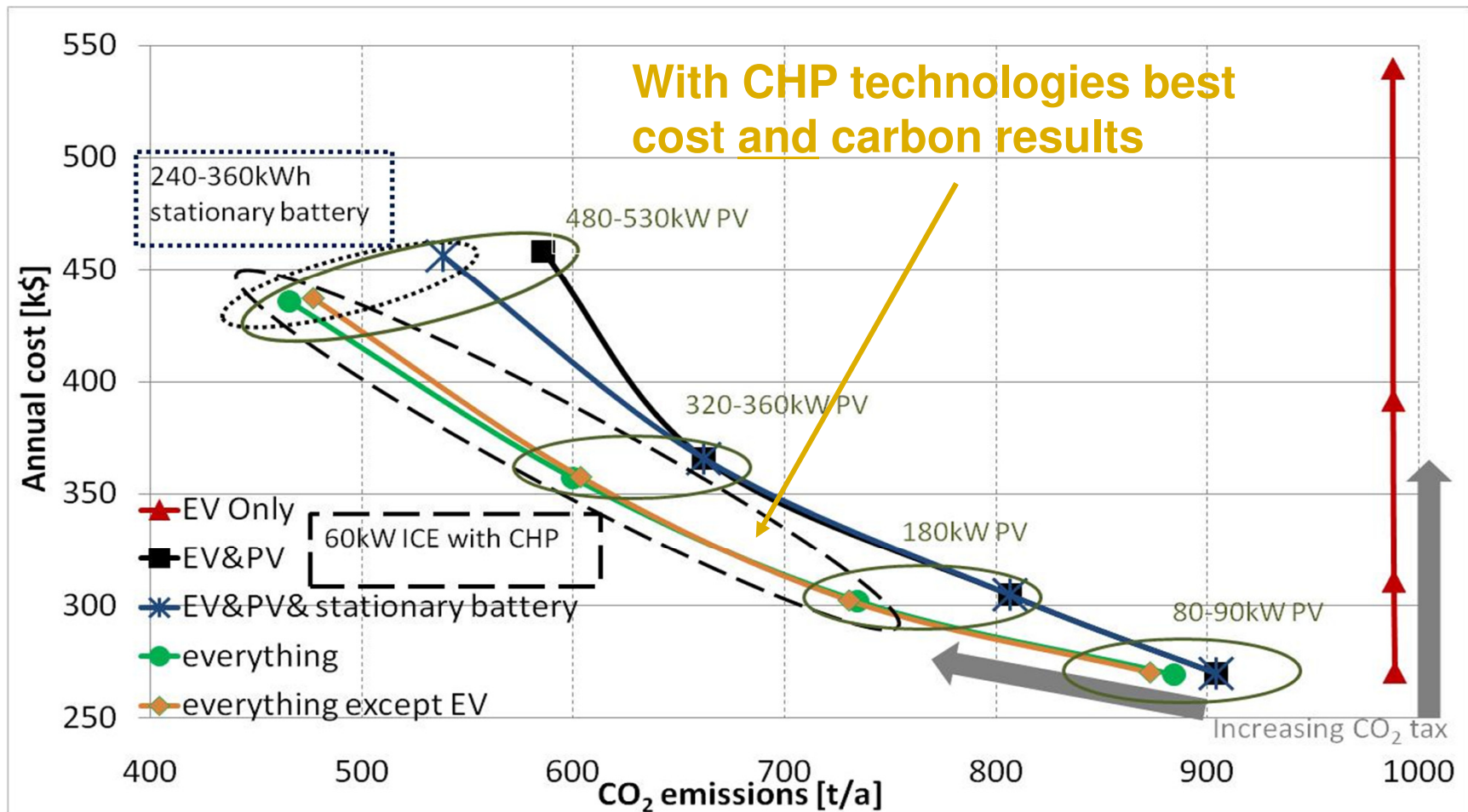
EV capacity vs. CO₂ tax



Building energy costs vs. CO₂ emissions



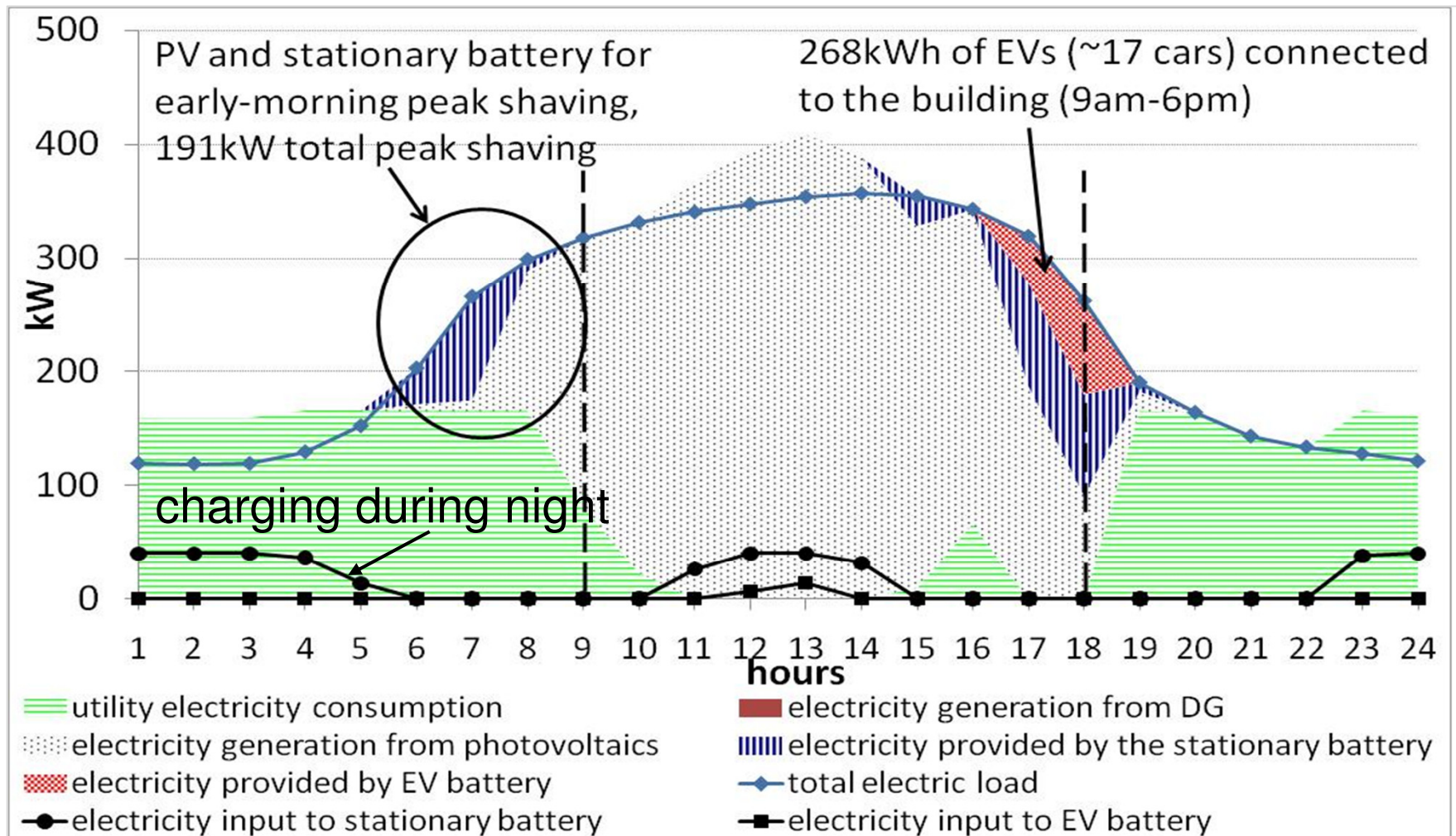
Annual Office Building Energy Costs and CO₂ Emissions subject to CO₂ Tax



Diurnal electricity pattern, highest CO₂ tax



EV&PV&stationary battery case, July weekday



Electric vehicle



Conclusions



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Building / tariffs



- in almost all cases no energy is transferred to the residence
- high CO₂ prices favor PV, but all its energy is used in the office building
- EV and stationary batteries absorb some electricity from PV and release it in the afternoon, when the PV output is down
- EVs are effectively used to reduce TOU and demand charges at the office building
- due to the limited connection time of EV batteries, stationary batteries and CHP are more attractive to the office building
- California macrogrid CO₂ emissions are very flat and more volatile CO₂ emissions would change the results.

More literature

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End



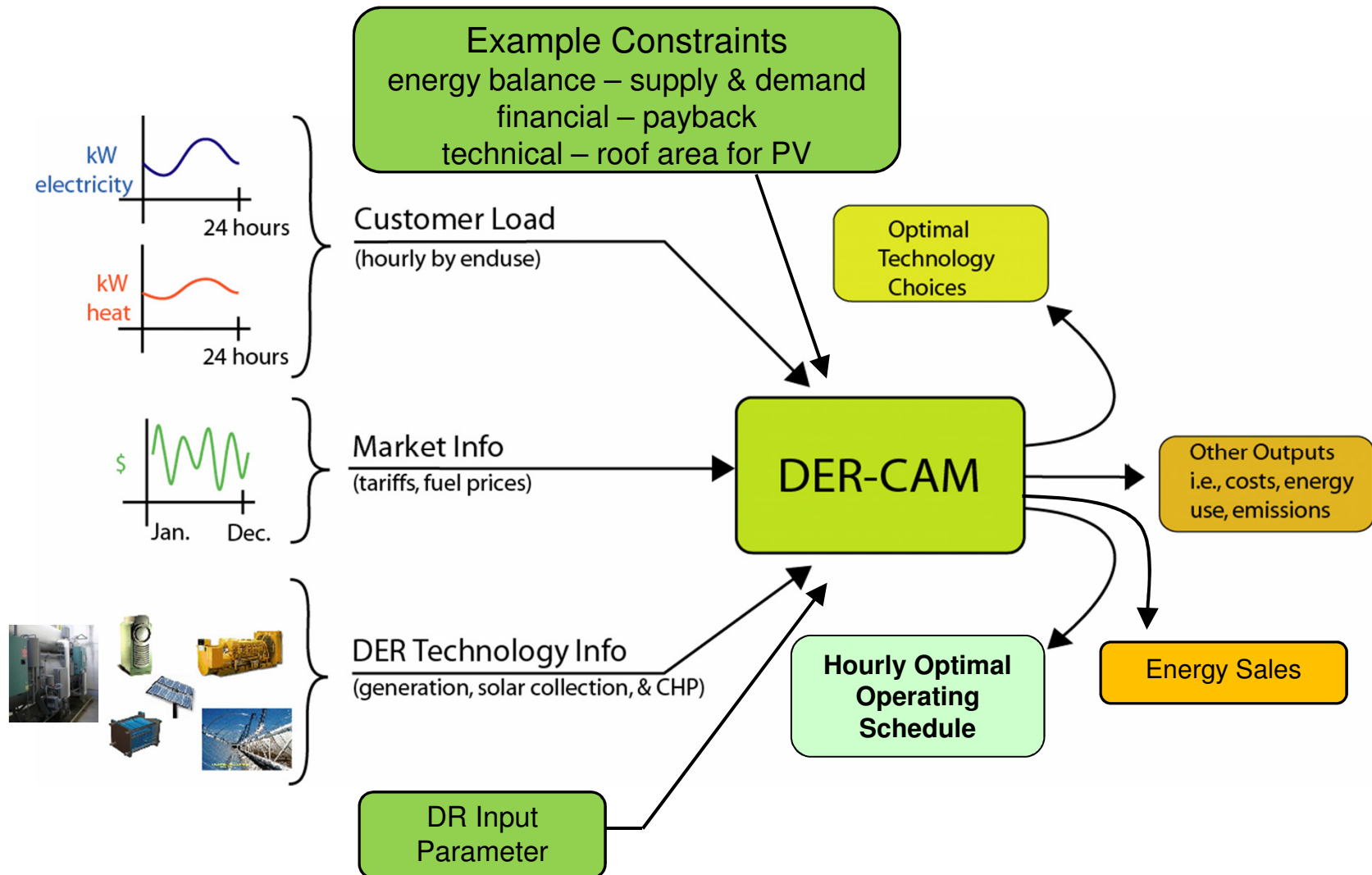
Thank you!

Questions and comments are very welcome.

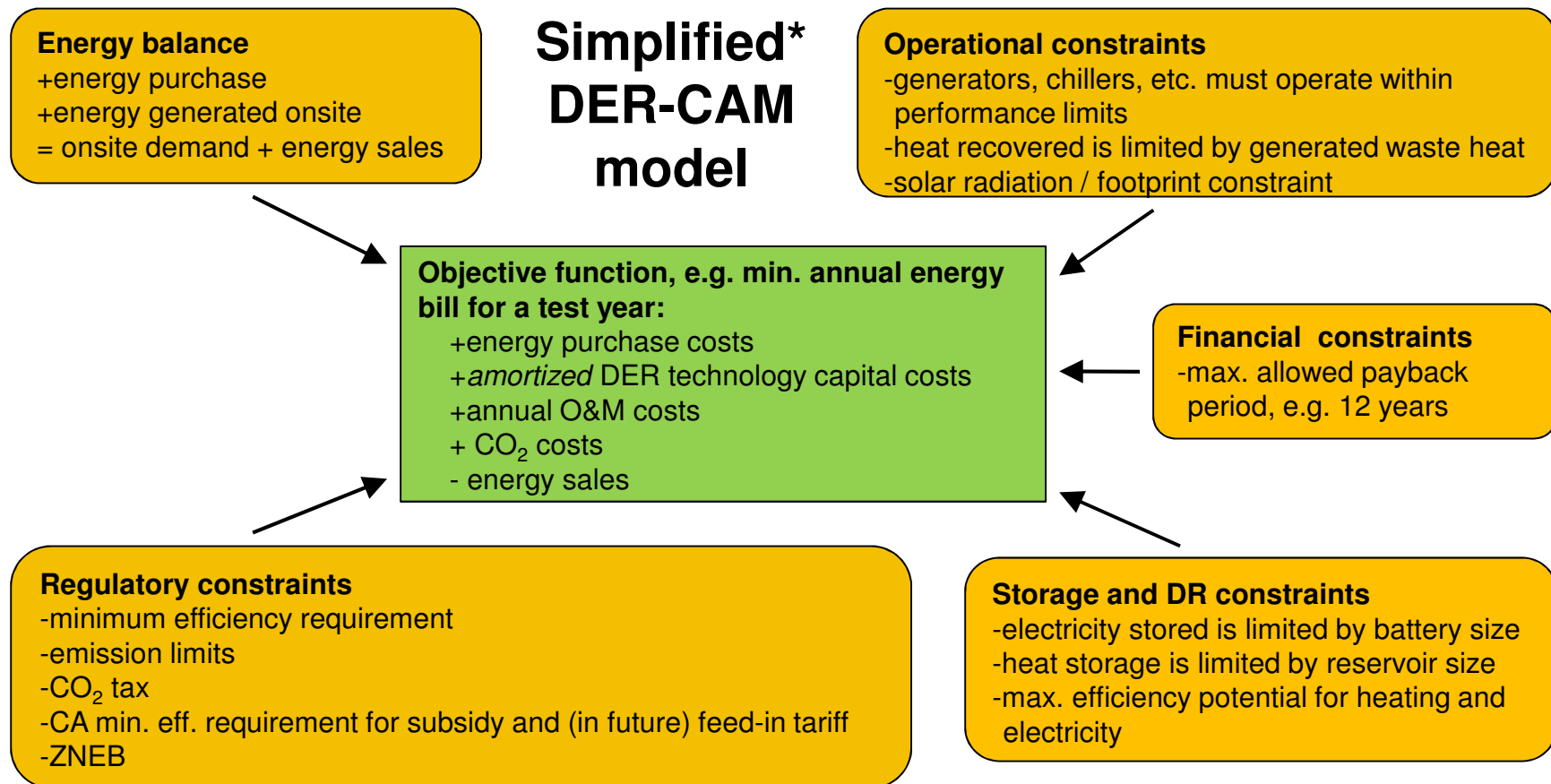


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High-level schematic



Representative MILP



*does not show all constraints